# Nanoscale Fabrication of Mesoscale Objects

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High-energy-density experiments (HEDE) are expected to play an important role in corroborating the improved Advanced Simulation and Computing (ASCI) physics codes that underlie the Stockpile Stewardship Program. To conduct these experiments, several improvements are needed—both in the diagnostics for measuring experimental results and in target fabrication. This project is working on a new LLNL capability for improving fabrication and characterization of mesoscale (millimeter size) objects with micrometer-size features at nanometer-scale accuracy for HEDE targets. Other applications include pinholes required for a phase-shifting diffraction interferometer, microporous electrodes in miniature fuel cells, remote sensors, and medical technologies. To create a fabrication capability that is deterministic, this research combines modeling and experiments.

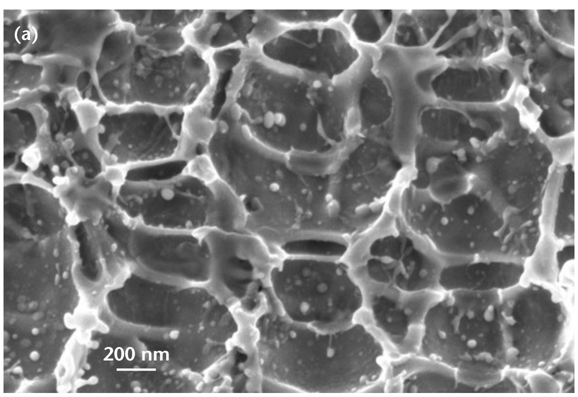
This project leverages LLNL expertise in modeling, simulation, and laser-surface interactions to develop a new capability for fabricating and characterizing mesoscale targets for weapons physics experiments in support of LLNL's stockpile stewardship mission.

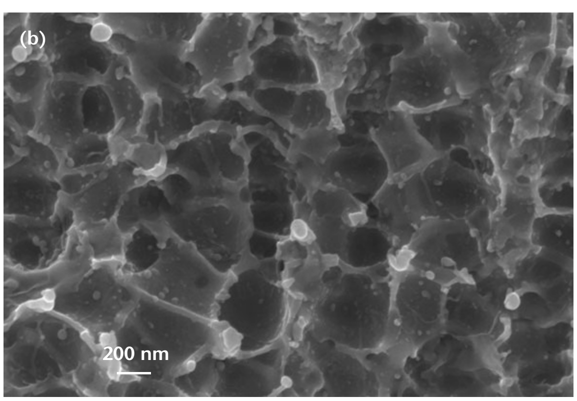
In FY02, we successfully combined three-dimensional (3-D) molecular dynamics (MD) modeling with the 1-D hydrocode, HYADES to take advantage of the strengths of each approach. First, the laser-material interaction with HYADES is tracked. Then, well after laser pulse termination and the relaxation of the electron subsystem, the density, velocity, pressure and temperature profiles are passed on as initial conditions for the MD simulator. For 150-fs laser pulses on copper, this approach predicts void nucleation to occur within about 20 nm of the surface.

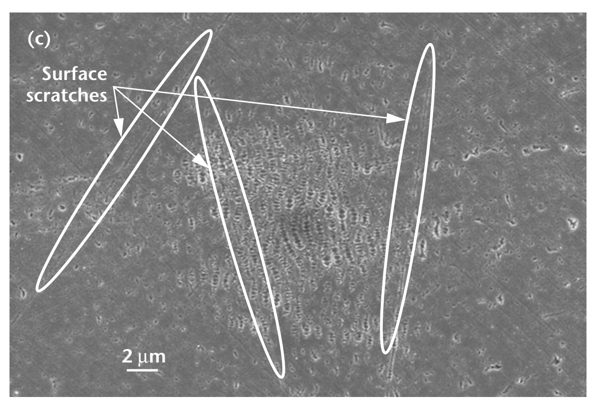
Experimentally, our studies included single-shot and multiple-shot ablation of single-crystal and polycrystalline, copper and gold targets, using 150-fs laser pulses at 800-nm wavelength. For laser pulses only slightly above the threshold for ablation, results show that the residual surface roughness is relatively independent of the total depth of the ablation crater [Figs. (a) and (b)]. We have also observed that initial surface scratches, like those in Fig. (c), tend to be nucleation sites for the micropits that are formed during ablation. During FY03, we plan to continue exploring the possibility of using submicrometer-spaced ridges, made by diamond turning of the surface prior to laser ablation, to "seed" and control the growth of these features.

Laser "polishing" could reduce the amplitude of submicrometer surface perturbations caused by ablation, without affecting the longer-length-scale pattern formed by this process. Using a Monte Carlo model of the crystal surface structure, we studied the effect of laser heating the object to temperatures near the melting point. Though effective, the time required was too great for efficient processing. However, by modeling laser pulses that produce a transient liquid layer of controlled thickness (surface melting), we predict that the time required to smooth the surface could be reduced dramatically. The trade-off between the smoothening and freezing times determines the duration, period, and intensity of the polishing pulses.

In FY03, we plan to use diamond-turned copper, gold, and nickel substrates to study the smoothening processes experimentally with excimer laser pulses at 193 nm.




*Photomicrographs of copper surfaces, showing little difference in surface roughness after ablation with (a) 5 and (b) 100 150-fs laser pulses at 800 nm. Microscale pock marks are seen in (c), some nucleating on initial surface scratches.*